Cruise Report LITTORINA
Wismar Bay
L19-06

20th–25th May 2019

Institute of Geosciences
Christian-Albrechts-University, Kiel

Leibniz Institute for Baltic Sea Research,
Warnemuende

1. Scientific Crew

Table 1 - Scientific crew

Nome	Institute
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2. Objectives of the cruise

The subsurface flow of water from the continent to coastal waters, regardless of fluid composition or driving force is called Submarine Groundwater Discharge (SGD). SGD consists of circulated seawater and groundwater, and both mix in the so-called subterranean estuary. Due to the many reactions that may occur in the subterranean estuary, SGD may have a substantial impact on the chemical composition of coastal ecosystems and biogeochemical cycles.

Radium (Ra) isotopes are usually enriched in SGD-derived coastal waters because they are released from solid sediments during the mixing of seawater and groundwater in the subterranean estuary. SGD which flows into the coastal sea is expected to be associated with Ra and, therefore, measurements of Ra isotopes in coastal waters can be used to quantify SGD. In combination with the determination of elemental compositions also SGD fluxes of e.g nutrients can be inferred.

First indications that SGD may occur in the Wismar Bay were observed during a Littorina cruise in April/May 2013. During this cruise, the radon and Ra isotope distribution were determined along the coastal line; and concentrations anomalies in the Wismar Bay indicated that SGD may play a role here. A further study based on a numerical groundwater model suggest that the amount of SGD flowing to the Wismar Bay is about $12x10^6$ m^3/a (Schafmeister and Darsow, 2011).

The objective of LITTORINA cruise L19-06 was to quantify possible SGD fluxes to the Wismar Bay through a mass balance of isotopes measured in coastal waters. Moreover, samples for major elements, trace metals, nutrients, Dissolved Organic Carbon (DOC), Dissolved Inorganic Carbon (DIC), sulfide, isotopes of water, $\delta^{34}S$ and $\delta^{18}O$ of sulfate, $\delta^{34}S$ of sulfide and $\delta^{13}C$ of DIC and DOC will allow the characterization of element sources, sinks and their potential transformations and for estimates of SGD-born element fluxes.

This multi-tracer approach will allow us to better understand the subsurface hydrology and biogeochemical processes as well as the associated element and water fluxes in a regional context, as an example for SGD in the southern Baltic Sea.

3. Narrative of cruise

Table 2 - Description of the activities during the cruise. The locations of the stations are explained in the Table 3.

Date	Activities
20.05.2019	▪Departure 09:00 from Kiel harbor in direction to Wismar Bay ▪At 4 pm first CTD station (Station 1) – and water sampling at 8m and 24m water depth. ▪Arrival at Wismar harbor at 7 pm.
21.05.2019	▪Departure 08:00 from Wismar harbor. ▪4 stations (Station 3, 4, 6 and 7) - CTD and water sampling. ▪1 station (Station 2) – CTD, water sampling at 4m, 8m and 1 water depths and core; ▪2 stations (Station 8 and 9) near the coast using rub boat –water sampling; ▪Arrival at Wismar harbor at 6 pm.
22.05.2019	▪Departure 08:00 from Wismar harbor; ▪7 stations (Station 13, 14, 15,16,17,18 and 19) – CTD and water sampling. ▪2 stations (Station 11 and 12)– CTD, water sampling at 2m and 8 m water depth and core;
23.05.2019	▪Departure 08:00 from Wismar harbor. ▪2 stations (Station 29 and 30) – CTD and water sampling; ▪2 stations (Station 20 and 31)– CTD, water sampling and core; ▪8 stations (Station 21, 22, 23, 24, 25, 26, 27 and 28) near the coast using the rub boat –water sampling; ▪Arrival at Wismar harbor at 6:30 pm.
24.05.2019	▪Departure 08:00 from Wismar harbor. ▪8 stations (Station 32, 33, 34, 35, 36, 37, 46 and 47) – CTD and water sampling; ▪8 stations (Station 38, 39, 40, 41, 42, 43, 44 and 45) near the coast using the rub boat; ▪Arrival at Kiel harbor at 10 pm.

4. On board methods

In total at 47 stations water sampling was performed (Figure 1 and Table 3).

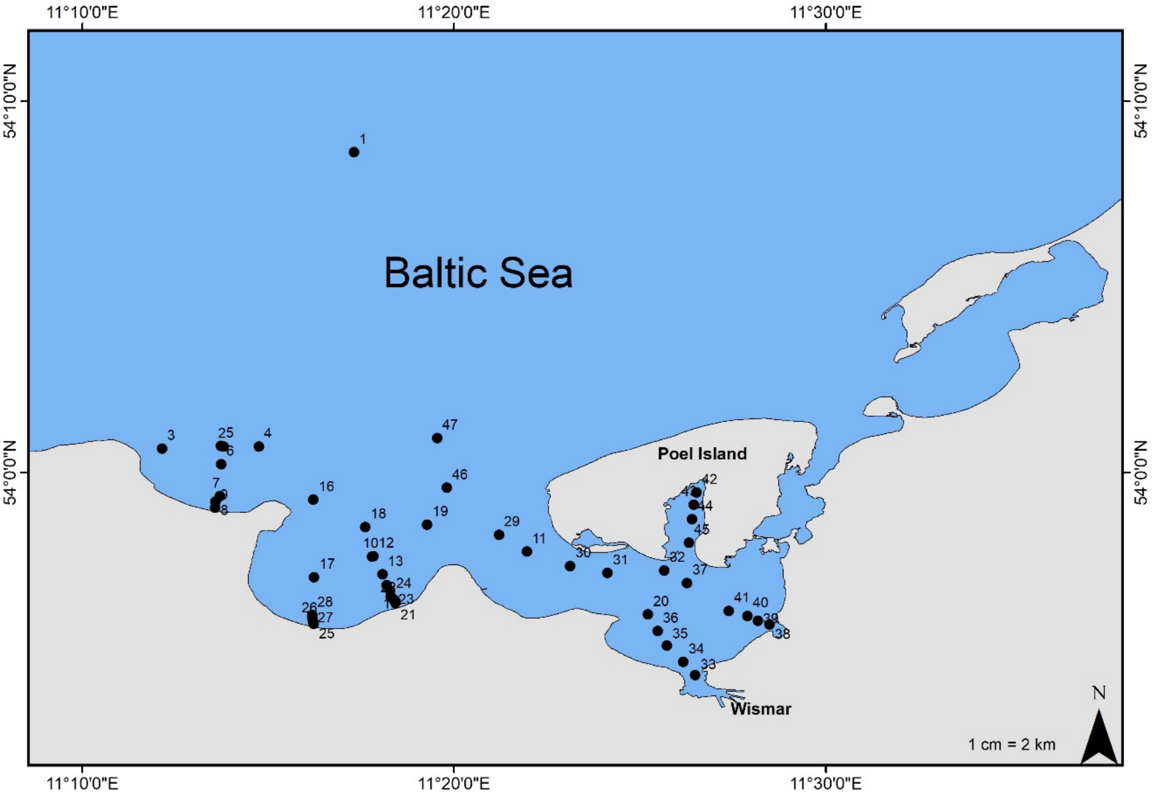

Figure 1: Study area with the sampling stations

4.1 Water sampling

At every station first a Conductivity-Temperature-Depth probe (CTD) was deployed in order to investigate the vertical water column structure. The salinity profile was used to identify the water depths for water sampling. Water samples were obtained using a WASP 5 submersible pump. About 100 liters of seawater was filtered and filled in barrels. Subsequently, water samples were taken using plastic syringes and filtered through 0.45 µm syringe filters for analysis of metals, nutrients, Dissolved Organic Carbon (DOC), Dissolved Inorganic Carbon (DIC), sulfate, isotopes of water, $\delta^{34}S$ and $\delta^{18}O$ of sulfate and $\delta^{13}C$ of DIC. The geochemical analysis will be conducted at the Leibniz Institute for Baltic Sea Research Warnemüende (IOW), Germany.
For the determination of radium isotopes about 100 liter of water was filtered over manganese (MnO_2) fiber which quantitatively adsorb Ra. The fibers were washed to remove excess salt, partly dried, and then measured on-board for ^{223}Ra and ^{224}Ra using a RaDeCC (Radium Delayed Coincidence Counting) system.
In total 52 seawater samples for radium and chemical elements were obtained.

At five across-shore transects located in shallow water depths water sampling was carried out using a rubber boat. At 20 stations surface water were pumped into 5 x 20 plastic canisters which were brought on-board for the further sub-sampling and filtration as described above.

4.2 Pore-water and sediment sampling

A Rumohr-Lot was used for sediment and pore water sampling. At each of the six sediment stations two cores were collected. The sediments of one core were sliced in 2cm to 5 cm slices for further chemical analysis of metals, Carbon-Nitrogen-Sulfur analyses and the determination of sediment grains size distribution. The second was used for pore water sampling using Rhizons (Figure 2) which were inserted horizontally into the sediments in 2 cm spacing. Pore waters were sampled for the analyses of metals, nutrients, DOC, DIC, sulfate, isotopes of water, $\delta^{34}S$ and $\delta^{18}O$ of sulfate, $\delta^{34}S$ of sulfide and $\delta^{13}C$ of DIC/DOC. On-board the ship the salinity and the pH of pore waters were measured using a refractometer and hand-held pH meter.

Figure 2: Pore water sampling of a sediment core

Table 3 – Station list with coordinates, water depths and sampling method

Stations	Coordinates		Water Depth (m)	Sampling
Station 1	54°08,626	11° 17,317	24	CTD, water and Ra sampling in 8m and 24m water depths.
Station 2	54°00,709	11° 13,804	18	CTD, water and Ra sampling in 4m, 8m and 16m depths and core.
Station 3	54°00,653	11° 12,154	6	CTD, water and Ra sampling in 2m depth.
Station 4	54°00,708	11° 14,751	14	CTD, water and Ra sampling at 2m depth.
Station 5	54°00,725	11° 13,732	14	CTD, water and Ra sampling in 2m depth.
Station 6	54°00,235	11° 13,739	13	CTD, water and Ra sampling in 2m depth.
Station 7	53°59,371	11° 13,701	9	CTD, water and Ra sampling in 2m depth.
Station 8	53°59,231	11° 13,585	9.3	Water and Ra sampling in 2m depth.
Station 9	53°59,062	11° 13,573	2.1	Water and Ra sampling in 1m depth.
Station 10	53°57,751	11° 17,799		core
Station 11	53°57,881	11° 21,968	9	CTD, water and Ra sampling in 2m and 8m depths and core.
Station 12	53°57,756	11° 17,831	8	CTD, water and Ra sampling in 2m and 8m depths and core.
Station 13	53°57,271	11° 18,078	8	CTD, water and Ra sampling in 2m depth.
Station 14	53°56,983	11° 18,195	7	CTD, water and Ra sampling in 2m depth.
Station 15	53°56,833	11° 18,281	7	CTD, water and Ra sampling in 2m depth.
Station 16	53°59,278	11° 16,221	6	CTD, water and Ra sampling in 2m depth.
Station 17	53°57,191	11° 16,237	7	CTD, water and Ra sampling in 2m depth.
Station 18	53°58,546	11° 17,616	7	CTD, water and Ra sampling in 2m depth.
Station 19	53°58,607	11° 19,280	9	CTD, water and Ra sampling in 2m depth.
Station 20	53°56,193	11° 25,217	3	CTD, water and Ra sampling in 2m depth.
Station 21	53°56,508	11° 18,427	1.5	Water and Ra sampling in 1m depth.
Station 22	53°56,562	11° 18,420	1.5	Water and Ra sampling in 1m depth.
Station 23	53°56,600	11° 18,368	1.5	Water and Ra sampling in 1m depth.
Station 24	53°56,671	11° 18,305	1.5	Water and Ra sampling in 1m depth.
Station 25	53°55,941	11° 16,230	1.5	Water and Ra sampling in 1m depth.
Station 26	53°56,012	11° 16,211	1.5	Water and Ra sampling in 1m depth.
Station 27	53°56,103	11° 16,192	1.5	Water and Ra sampling in 1m depth.
Station 28	53°56,173	11° 16,188	1.5	Water and Ra sampling in 1m depth.
Station 29	53°58,333	11° 21,214	2	Water and Ra sampling in 1m depth.
Station 30	53°57,495	11° 23,130	7	Water and Ra sampling in 2m depth.
Station 31	53°57,308	11° 24,132	4	Water and Ra sampling in 1m depth and core.
Station 32	53°57,374	11° 25,657	4	CTD, water and Ra sampling in 2m depth.
Station 33	53°54,562	11° 26,488	7	CTD, water and Ra sampling in 2m depth.
Station 34	53°54,912	11° 26,171	3	CTD, water and Ra sampling in 2m depth.
Station 35	53°55,351	11° 25,733	2.5	CTD, water and Ra sampling in 2m depth.
Station 36	53°55,742	11° 25,479	2.5	CTD, water and Ra sampling in 2m depth.
Station 37	53°57,037	11° 26,273	4	CTD, water and Ra sampling in 2m depth.
Station 38	53°55,921	11° 28,489	1	Water and Ra sampling in 0.5m depth.
Station 39	53°56,015	11° 28,177	1	Water and Ra sampling in 0.5m depth.

Station 40	53°56,150	11° 27,898	1	Water and Ra sampling in 0.5m depth.
Station 41	53°56,289	11° 27,395	1	Water and Ra sampling in 0.5m depth.
Station 42	53°59,473	11° 26,524	1	Water and Ra sampling in 0.5m depth.
Station 43	53°59,145	11° 26,455	1	Water and Ra sampling in 0.5m depth.
Station 44	53°58,756	11° 26,407	1	Water and Ra sampling in 0.5m depth.
Station 45	53°58,119	11° 26,322	1	Water and Ra sampling in 0.5m depth.
Station 46	53°59,600	11° 19,812	9	CTD, water and Ra sampling in 2m depth.
Station 47	54°00,938	11° 19,550	10	CTD, water and Ra sampling in 2m depth.

5. **First on-board results**

Figure 3 shows the salinity profiles of the water column at the stations investigated. At most stations the water column is well mixed down to ~6m water depth. At stations 11 and 18 a salinity increase below 6 m depth meters was observed.
Figure 4 shows salinity distribution in sediment pore waters of the cores investigated. At stations 10 and 11 a substantial freshening of pore waters with increasing sediment depth is observed suggesting a freshwater input via SGD.

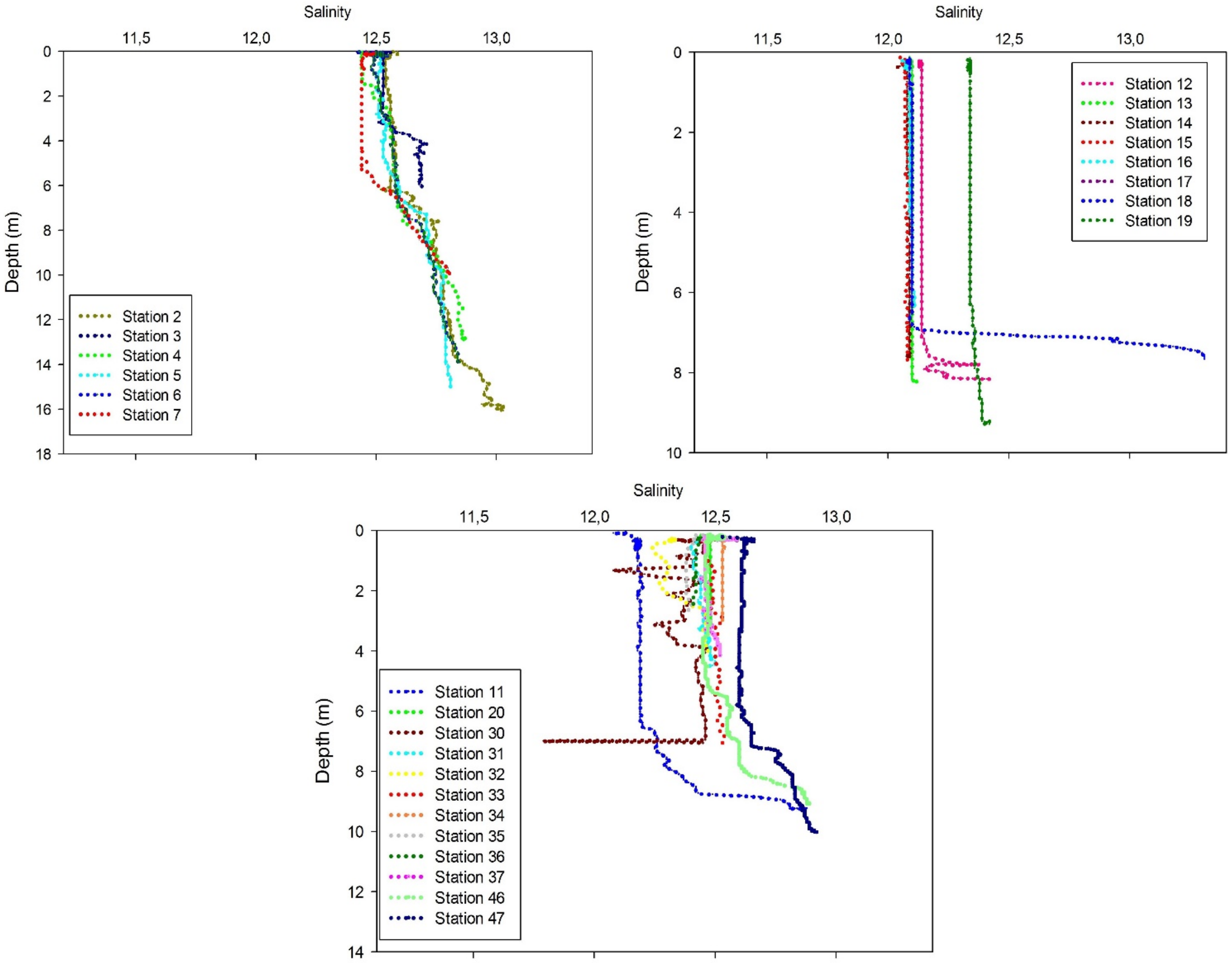

Figure 3: Salinity profiles at the stations investigated

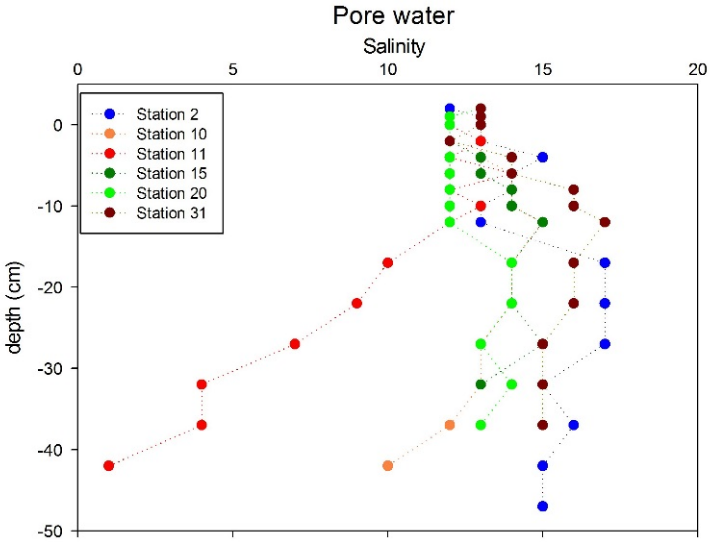

Figure 4: Salinity distribution in sediment pore waters; an influence of freshwater is observed at stations 10 and 11

6. Acknowledgements

We would like to acknowledge the excellent support by captain and crew during the cruise.

Figure 5: Participants of LITTORINA L19-06

7. References

Schafmeister, M.-T. and Darsow, A. (2011) Potential Change in Groundwater Discharge as Response to Varying Climatic Conditions – An Experimental Model Study at Catchment Scale, in: Harff, J., Björck, S., Hoth, P. (Eds.), **The Baltic Sea Basin**. Springer Berlin Heidelberg, pp. 391-404.